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Mountain Hemlock

A BIBLIOGRAPHY WITH ABSTRACTS

compiled by

JERRY F. FRANKLIN

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE · FOREST SERVICE

A common sequence in forest succession in the Cascade Range of Washington and Oregon. Mountain hemlock replacing lodgepole pine on an old high-elevation burn. Located at 4,800-foot elevation on the Mount Hood National Forest.

Research Paper 51

MOUNTAIN HEMLOCK--

A BIBLIOGRAPHY WITH ABSTRACTS

Compiled by Jerry F. Franklin

October 1962

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
R. W. Cowlin, Director
Portland, Oregon

U.S. FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

FOREWORD

This bibliography lists references pertaining to mountain hemlock (Tsuga mertensiana (Bong.) Carr.) found in North American and European literature for individuals interested in this species. The author has attempted to include all references which might conceivably provide useful information on this species; abstracts are provided for those considered most significant. Articles are listed alphabetically by author. A list of common and scientific names of tree species mentioned is found on page 50.

The author would appreciate having additional references to mountain hemlock brought to his attention.

Appreciation is expressed for the assistance of Miss Marie Gould, librarian at the Pacific Northwest Forest and Range Experiment Station, for assistance in obtaining some of the references for examination.

BIBLIOGRAPHY

1. Abrams, LeRoy.
   1923. An illustrated flora of the Pacific States, Washington, Oregon, and California. Vol. 1, Ophioglossaceae to Aristolochiaceae. 557 pp., illus. Stanford Univ.: Stanford Univ. Press.

2. Alexander, R. R.
   1958. Silvical characteristics of Engelmann spruce.* U.S. Forest Serv. Rocky Mountain Forest & Range Expt. Sta. Sta. Paper 31, 20 pp., illus.

3. _____
   1958. Silvical characteristics of subalpine fir. * U.S. Forest Serv. Rocky Mountain Forest & Range Expt. Sta. Sta. Paper 32, 15 pp., illus.

4. Aller, Alvin R.
   1956. A taxonomic and ecologic study of the flora of Monument Peak, Oregon. Amer. Midland Nat. 56: 454-472, illus.

   A small group of mountain hemlock and Alaska cedar is found at the summit of this 4,700-foot peak in the western Cascades of Oregon.

5. Anderson, J. P.
   1959. Flora of Alaska and adjacent parts of Canada. 543 pp., illus. Ames: Iowa State Univ. Press.

6. Andrews, H. J., and Cowlin, R. W.
   1940. Forest resources of the Douglas-fir region. U.S. Dept. Agr. Misc. Pub. 389, 169 pp., illus.

   There was estimated to be 1,311,400,000 cubic feet of mountain hemlock in this region.

7. Applegate, Elmer I.
   1939. Plants of Crater Lake National Park. Amer. Midland Nat. 22: 225-314, illus.

   Mountain hemlock typifies the Hudsonian zone which is encountered at about 6,000 feet. It occurs with whitebark pine, Shasta red fir, and subalpine fir, and constitutes the main body of the "deep and somber"

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forest clothing Mount Mazama proper, reaching to the rim of the Crater on both sides of the divide and to the top of Mount Scott along with white-bark pine.

8. Babb, M. F.
1959. Ornamental trees and shrubs for Alaska. Alaska Agr. Expt. Sta. Bul. 24, 39 pp., illus.

9. _____
1959. Propagation of woody plants by seed. Alaska Agr. Expt. Sta. Bul. 26, 12 pp., illus.

10. Bailey, Harold E., and Bailey, Virginia Long.
1941. Forests and trees of the western national parks. U.S. Dept. Int. Natl. Park Serv. Conserv. Bul. 6, 129 pp., illus.

11. Bailey, L. H.
1933. The cultivated conifers in North America. 404 pp., illus. New York: The Macmillan Co.

12. Bailey, Vernon.
1936. The mammals and life zones of Oregon. U.S. Bur. Biol. Survey North Amer. Fauna 55, 416 pp., illus.

13. Baker, Frederick S.
1949. A revised tolerance table. Jour. Forestry 47: 179-181.

Mountain hemlock is rated "tolerant" in this five-class table, a classification second only to "very tolerant" in degree of intolerance. The table was developed from published statements and questionnaires returned by queried foresters.

14. Baker, William H.
1951. Plants of Fairview Mountain, Calapooya Range, Oregon. Amer. Midland Nat. 46: 132-173, illus.

Mountain hemlock occurs on the north and west slopes of this 5,733-foot peak. It is characteristic of the Hudsonian zone and the principal tree at timberline.

15. Baron, Frank J., and Schubert, Gilbert H.
1961. California cone crop--1961.* U.S. Forest Serv. Pac. SW. Forest & Range Expt. Sta. Res. Note 188, 8 pp., illus.

16. Benson, Gilbert Thereon.
1930. The trees and shrubs of western Oregon. Contrib. Dudley Herb. Stanford Univ. Vol. 2. 170 pp., illus. Stanford Univ.: Stanford Univ. Press.

An annotated list with synonyms, type locality, range, and list of cited specimens (mostly from Dudley Herbarium).

17. Billings, W. D.
1954. Nevada trees. Ed. 2, Nev. Agr. Ext. Serv. Bul. 94, 125 pp., illus.

18. Bjarnason, H.
1951. A brief report on the reforestation of Iceland. Skógrackt Rikisins, Reykjavík. 14 pp.

19. Bowers, Nathan A.
1942. Cone-bearing trees of the Pacific Coast. 169 pp., illus. New York, London: Whittlesey House, McGraw-Hill Book Co., Inc.

20. Boyce, J. S.
1930. Decay in Pacific Northwest conifers. Yale Univ. Osborn Bot. Lab. Bul. 1, 51 pp., illus.

21. Boyce, John S.
1943. Host relationships and distribution of conifer rusts in the United States and Canada. Conn. Acad. Sci. Trans. 35: 329-482.

Two rusts are known to attack mountain hemlock.

22. Boyce, John Shaw.
1948. Forest pathology. Ed. 2, 550 pp., illus. New York, Toronto [etc.]: McGraw-Hill Book Co., Inc.

Brown stringy rot (Echinodontium tinctorium), a trunk rot, and a root and butt rot (Fomes annosus) occur on mountain hemlock. Western dwarfmistletoe (Arceuthobium campylopodum forma tsugensis) also attacks it. Hemlock wood is "intermediate-nondurable" in terms of decay resistance, only the "nondurable" class being less resistant.

23. Brink, V. C.
1959. A directional change in the subalpine forest-heath ecotone in Garibaldi Park, British Columbia. Ecol. 40: 10-16, illus.

This study was conducted in the coast mountain system of British Columbia about 40 miles north of Vancouver. Mountain hemlock, along

with silver fir and yellow cedar, is the principal constituent of the lower subalpine forest located at 3,500 to 5,000 feet. It also occurs in the Krummholz region where subalpine fir is the most important species. Observations in the upper subalpine forest and meadow area indicate alpine fir and mountain hemlock are invading the heath communities (Phyllodoce-Cassiope heath) between forest stands and groves. This is attributed to changing climatic conditions, in particular, diminishing snow cover.

24. British Forestry Commission.
1957. Exotic forest trees in Great Britain. Brit. Forestry Comn. Bul. 30, 167 pp., illus.

25. Britton, Nathaniel Lord, and Shafer, John Adolph.
1908. North American trees; being descriptions and illustrations of the trees growing independently of cultivation in North America, north of Mexico and the West Indies. 894 pp., illus. New York: Henry Holt & Co.

26. Brockman, C. Frank.
1933. The forests of Mt. Rainier. Nat. Hist. 33: 523-532, illus.

27. _____
1947. Flora of Mount Rainier National Park. U.S. Dept. Int., 170 pp., illus.

Mountain hemlock is a characteristic tree of the Hudsonian zone on Mount Rainier (Washington).

28. _____
1949. Trees of Mount Rainier National Park. 49 pp., illus. Seattle: Univ. Wash. Press.

29. _____
1955. Mountain hemlock, Tsuga mertensiana (Bong.) Carr. Univ. Wash. Arboretum Bul. 18: 9, illus.

30. Brockman, Christian Frank.
1931. Forests and timber types of Mount Rainier National Park. Unpublished M.S. thesis on file at Univ. Wash. 54 pp., illus.

Mountain hemlock is a principal tree species in 4 of the 15 timber (cover) types recognized and occurs in 3 others. Brockman lists principal, secondary, and minor tree species; underbrush and typical ground cover; and herbaceous type indicators for each and discusses the types briefly.

31. Buckhorn, W. J., and Orr, P. W.
1961. Forest insect conditions in the Pacific Northwest during 1960.* U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 40 pp., illus.

Reports a small outbreak of black-headed budworm (Acleris variana (Fern.)) on mountain hemlock, western hemlock, Douglas-fir, and grand fir on the Mount Hood National Forest.

32. Burlison, Vernon H., Guernsey, Roger L., and Johnson, Frederic D.
1958. Trees of Idaho. Idaho Agr. Ext. Serv. Bul. 289, 23 pp., illus.

33. Burns, Findley.
1911. The Crater National Forest: Its resources and their conservation. U.S. Dept. Agr. Forest Serv. Bul. 100, 20 pp., illus.

34. Butters, F. K.
1914. Some peculiar cases of plant distribution in the Selkirk Mountains, British Columbia. Minn. Bot. Studies 4: 313-331, illus.

Compares vegetation of the Selkirks and Canadian Rockies. Butters explains peculiarities of plant distribution largely on the basis of soil parent materials. Western and mountain hemlock were rare and stunted on calcareous portions of the Selkirks and in the Canadian Rockies which contrasted with their size and abundance in neighboring adjacent valleys and the Selkirks in general.

35. _____
1932. Flora of the Glacier District. Canad. Alpine Jour. 21: 139-147.

Mountain and western hemlock are the most characteristic trees of the Glacier District (Selkirk Mountains). They form from 50 to 90 percent of most forests below 5,300-foot elevation with either predominating. Above 5,300 feet to timberline, mountain hemlock occurs without western hemlock and may form 80 percent of the forest. It avoids limestone and is not a good pioneer, rarely being present in recently disturbed areas such as moraines, avalanche tracts, or burns.

36. Campo-Duplan, M. van.
1947. Notes sur le pollen des hybrides chez les Abiétinées. Toulouse Univ. Lab. Forest. Trav., tome 1, vol. 4, art. 82, 5 pp., illus. (Also: Toulouse Soc. d'Hist. Nat. Bul. 84: 73-77, illus. 1949.)

37. Campo-Duplan, M. van.
1950. Recherches sur la phylogénie des Abiétinées d'aprés leurs grains de pollen. Toulouse Univ. Lab. Forest. Trav., tome 2, vol. 4, art. 1, 183 pp., illus.

38. _____ and Gaussen, H.
1948. Sur quatre hybrides de genres chez les Abiétinées. (Four intergeneric hybrids among the Abietineae.) Toulouse Univ. Lab. Forest. Trav., tome 1, vol. 4, art. 24, 15 pp., illus. (Also: Toulouse Soc. d'Hist. Nat. Bul. 84: 95-109, illus. 1949.)

On the basis of a detailed anatomical and morphological study, the authors decide mountain hemlock ("Tsuga hookeriana") is a hybrid between Tsuga heterophylla and Picea sitchensis which they rename Tsugo-Picea hookeriana. Tsuga crassifolia (supposedly a California variety of T. hookeriana) is a Picea engelmannii-Tsugo-Picea hookeriana hybrid which they rename Tsugo-Piceo-Picea crassifolia. Tsuga jeffreyi, which is a T. heterophylla-T. hookeriana hybrid, they rename Tsugo-Picea-Tsuga jeffreyi. They discuss genetic and phyletic aspects of these hybrids.

39. Canada Department of Resources and Development Forestry Branch.
1951. Canadian woods--their properties and uses. Ed. 2, 367 pp., illus. Ottawa: Edmond Cloutier, King's Printer and Controller of Stationery.

40. Canada Dominion Forest Service.
1961. Native trees of Canada. Canada Dept. Mines and Resources, Dominion Forest Serv. Bul. 61, ed. 6, 291 pp., illus.

41. Carl, G. Clifford, Guiguet, C. J., and Hardy, George A.
1952. A natural history survey of the Manning Park area, British Columbia. Brit. Columbia Provisnl. Mus. Occas. Paper 9, 130 pp., illus.

42. Carpenter, Stanley Barton.
1961. A description of the Pacific silver fir-hemlock forest on the western slopes of the Cascade Mountains in the vicinity of Mount Rainier, Washington. Unpublished M.F. thesis on file Univ. Wash. 55 pp., illus.

Mountain hemlock is a constituent of three of the five forest types recognized in this study: edaphic Canadian type, upper Canadian type, and Canadian zone-Hudsonian zone transition type. It is common only in the latter. Data on stand structure, tree growth, and species composition of a typical stand in each type are provided. Successional relations and soils in each type are also briefly discussed.

43. Chapman, R. M., and Shacklette, H. T.
1960. Geochemical exploration in Alaska. U.S. Geol. Survey Prof. Paper 400-B: 104-107, illus.

44. Church, James E.
1942. Snow and snow surveying; ice. In Physics of the Earth-IX. Hydrol. Ed. by Oscar E. Meinzer, pp. 83-148. New York: McGraw-Hill Book Co., Inc.

Notes that a mountain hemlock forest (in California) meets the requirements for the "ideal forest for the conservation of snow."

45. Collingwood, G. H.
1937. Mountain hemlock, Tsuga mertensiana (Bongard) Sargent. Amer. Forests 43: 450-451, illus.

46. _____ and Brush, Warren D.
1955. Knowing your trees. New and rev. ed., 328 pp., illus. Washington, D.C.: Amer. Forestry Assoc.

47. Cooke, William Bridge.
1940. Flora of Mount Shasta. Amer. Midland Nat. 23: 497-572, illus.

"A large grove [of mountain hemlock], dominating the forest, displaces the Shasta Fir in the Upper Canadian Zone at Squaw Valley Creek meadows. A smaller grove shares the borders of Panther Creek meadows with the Shasta Fir. Isolated groves occur at moist places around the mountain below timberline such as the small grove north of Diller Canyon and the scattered trees in the Shasta Fir forest between Squaw Valley Creek and Mud Creek Canyon. Where it occurs in quantity it extends in dwarfed individuals above timberline." Additional information is provided in the section on life zones.

48. Cooke, Wm. Bridge, and Shaw, Charles Gardner.
1952-53. The Suksdorf fungus collections. Wash. State Col. Res. Studies 20: 135-145; 21: 3-57.

49. Cooper, William S.
1931. The layering habit in Sitka spruce and the two western hemlocks. Bot. Gaz. 91: 441-451, illus.

Observations of reproduction by layering of mountain hemlock, western hemlock, and Sitka spruce.

50. Cooper, William S.
1931. The seed-plants and ferns of the Glacier Bay National Monument, Alaska. Torrey Bot. Club Bul. 57: 327-338.

Young individuals of Tsuga mertensiana occur frequently in the Sitka spruce forests of the lower bay. Its establishment in abundance, along with western hemlock, marks complete attainment of the regional climax. It also occurs occasionally in pioneer communities and infrequently in the alder-willow thicket stage of succession.

51. _____
1931. A third expedition to Glacier Bay, Alaska. Ecol. 12: 61-95, illus.

52. _____
1939. A fourth expedition to Glacier Bay, Alaska. Ecol. 20: 130-155, illus.

53. _____
1942. Vegetation of the Prince William Sound region, Alaska; with a brief excursion into post-Pleistocene climatic history. Ecol. Monog. 12: 1-22, illus.

Mountain hemlock is the most important tree species in this region often forming almost pure stands, although western hemlock, Sitka spruce, and Alaska cedar are also present. Average tree diameter is 1 to 2 feet; height, 40 to 50 feet, with maximums of 3 and 100 feet, respectively. Occurrence of forest vegetation along six fiords (passages) is discussed in detail. Three have essentially the same vegetation as the outer shores of the Sound; three have forest which is confined to small patches. The restriction on the latter is probably due to a more severe climate resulting from extensive glacial masses around them.

Two types of tundra are also described--an Empetrum heath and Carex bog. Low, matted mountain hemlocks occur on the bog. These are small, have much dead wood, occur singly or in groups, and are frequently very old. Mountain hemlock is especially common on the heath in a transition zone which sometimes occurs between the heath and the forest.

54. _____
1957. Vegetation of the northwest-American province. Pac. Sci. Cong. Proc. 8(4): 133-138.

55. Cooper, William Skinner.
1923. The recent ecological history of Glacier Bay, Alaska: I. The interglacial forests of Glacier Bay. Ecol. 4: 93-128, illus.

During the period of contracted ice fields which preceded the last glacial advance (culminating about one and a half centuries ago), the shores of Glacier Bay were densely forested from water's edge to timberline (about 2, 500 feet). In character the forest was identical with the mature climax of southeastern Alaska today, i.e., Sitka spruce and western and/or mountain hemlock. Trees up to 38 inches in diameter were examined. In the lower bay region, which was free of ice longer, hemlocks were more important, indicating the forest had approached nearer to the climax.

56. _____
1923. The recent ecological history of Glacier Bay, Alaska: II. The present vegetation cycle. Ecol. 4: 223-246, illus.

Describes vegetational development on rock, moraine, and gravels around Glacier Bay. Following an initial herbaceous and shrubby stage is the first forest stage composed of Sitka spruce and cottonwood. Scattered western and mountain hemlocks may be represented in the understory, but they are most important in the climax forest. Representation of mountain hemlock increased from 5 percent of the stations examined in the pioneer stage to 25 percent in the climax forest.

57. _____
1924. The forests of Glacier Bay--present, past, and yet unborn. Jour. Forestry 22: 16-23, illus.

58. Crocker, Robert L., and Dickson, B. A.
1957. Soil development on the recessional moraines of the Herbert and Mendenhall Glaciers, south-eastern Alaska. Jour. Ecol. 45: 169-185, illus.

59. _____ and Major, Jack.
1955. Soil development in relation to vegetation and surface age at Glacier Bay, Alaska. Jour. Ecol. 43: 427-448, illus.

60. Dahms, Walter G.
1958. Silvical characteristics of mountain hemlock.* U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Silvical Ser. 11, 8 pp., illus.

Summarizes much of what is known about the autecology of mountain hemlock. Includes some information not published elsewhere.

61. Dallimore, W., and Jackson, A. Bruce.
1948. A handbook of Coniferae including Ginkgoaceae. Ed. 3, 682 pp., illus. London: Edward Arnold & Co.

Dendrological reference. Notes ornamental value of mountain hemlock and a variety argentea which is distinguished by very glaucous leaves.

62. Daubenmire, R.
1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecol. Monog. 22: 301-330, illus.

Mountain hemlock is confined to the Picea engelmannii-Abies lasiocarpa zone and occurs on all three habitat types (associations) delimited within this zone. It is a climax dominant and may exist in mixture with Engelmann spruce and/or subalpine fir or dominate to the exclusion of these two trees. There were no floristic or accompanying ecological peculiarities which justified splitting off distinctive associations and giving nomenclatorial recognition to the areas where mountain hemlock mingles with or supplants the spruce and fir.

63. Daubenmire, R. F.
1943. Vegetational zonation in the Rocky Mountains. Bot. Rev. 9: 325-393.

64. _____
1946. The life zone problem in the northern intermountain region. Northwest Sci. 20: 28-38, illus.

65. Daubenmire, Rexford.
1953. Classification of the conifer forests of eastern Washington and northern Idaho. Northwest Sci. 27: 17-24.

66. Davidson, John.
1927. Conifers, junipers and yew: gymnosperms of British Columbia. 72 pp., illus. London: T. Fisher Unwin Ltd.

67. Davis, Ray J.
1952. Flora of Idaho. 828 pp. Dubuque: Wm. C. Brown Co.

68. Deters, Merrill E.
1962. The Northern Rocky Mountain Region. In Regional silviculture of the United States, ed. by John W. Barrett, pp. 406-459, illus. New York: The Ronald Press Co.

69. Dixon, Dorothy.
1961. These are the champs. Amer. Forests 67(1): 41-46, 48-50, illus.

The largest mountain hemlock on record is 21 feet 9 inches in circumference at 4-1/2 feet, 118 feet tall, and has a crown spread of 83 feet 7 inches. It is found in Alpine County, Calif.

70. Dodwell, Arthur, and Rixon, Theodore F.
1900. Olympic Forest Reserve, Washington. U.S. Geol. Survey 21st Ann. Rpt. 1899-1900, Pt. 5, Forest Reserves: 151-208, illus.

71. Downing, George L.
1959. Hemlock sawfly. U.S. Dept. Agr. Forest Pest Leaflet 31, 4 pp., illus.

72. Doyle, J., and Kane, A.
1943. Pollination in Tsuga pattoniana and in species of Abies and Picea. Sci. Proc. R. Dublin Soc. 23(n.s.): 57-70.

Observations are made of ovular structure in relation to pollen reception and pollen behavior in mountain hemlock. Pollen grains are winged and its pollination mechanism differs from that described for other species of hemlock. The pollen is caught anywhere on the surface of a spreading micropylar flare, the tubes growing over the stigmatic surface to enter the nucellus tip, which is freely exposed. The pollen tubes appear to have "poorer growth power."

73. Drummond, John.
1956. Trees native to Montana. Mont. Ext. Serv. Bul. 257 (rev.), 47 pp., illus.

74. Duffield, John W.
1950. Review of "Sur quatre hybrides de genres chez les Abietinees" (On four inter-genus hybrids in the Abietineae.), by Mme. van Campo-Duplan and H. Gaussen. Jour. Forestry 48: 440.

Duffield raises two major objections to this article (which is cited earlier in this bibliography):

One would expect crosses to be often repeated, to find back-crosses of hybrids and numerous segregants as the result of interbreeding among the hybrids if, as the writers believe, the hybrids are still in contact. So far as Duffield knows there have been no such hybrid swarms found.

The writers considered exclusively the present day distribution of the species under consideration in formulating their hypothesis.

75. Ebell, Lorne F., and Schmidt, Ralph L.
1960. Effect of elevation and climatic factors on production and dispersal of coniferous tree pollen. Abstract in Soc. Amer. Foresters Proc. 1959: 39.

Mountain hemlock was the last to flower of 10 species included in this study.

76. Eliot, Willard Ayres, and McLean, G. B.
1948. Forest trees of the Pacific Coast. New ed., 565 pp., illus. New York: G. P. Putnam's Sons.

77. Elwes, Henry John, and Henry, Augustine.
1907. The trees of Great Britain and Ireland. Vol. 2, pp. 201-450, illus. Edinburgh: Privately printed.

78. Engelmann, George.
1880. Abietineae of California. Bot. Calif., vol. 11, pp. 117-128.

79. _____
1882. Tsuga pattoniana and hookeriana. Gard. Chron. 17: 145.

80. Engstrom, W. H.
1953. Oregon cone crop, 1953.* Oreg. State Bd. Forestry Res. Note 13, 6 pp., illus.

81. _____
1954. Oregon cone crop, 1954.* Oreg. State Bd. Forestry Res. Note 16, 7 pp.

82. Farr, Edith M.
1907. Contributions to a catalogue of the flora of the Canadian Rocky Mountains and the Selkirk Range. Univ. Penn. Bot. Lab. Contrib. 31, 88 pp.

83. Ferré, Y. de.
1952. Les formes de jeunesse des Abiétacées. Ontogénie-phylogénie. (Juvenile forms of the Abietineae. Ontogeny and phylogeny.) Toulouse Univ. Lab. Forest. Trav., tome 2, vol. 3, art. 1, 284 pp., illus.

Data on the characteristics of mountain hemlock (listed as Tsugo-Picea hookeriana) at different stages during juvenile development.

84. Flett, J. B.
1922. Features of the flora of Mount Rainier National Park. U.S. Dept. Int. Natl. Park Serv., 50 pp., illus.

85. Fleusborg, C. E.
1950. Fra Islands skovsag. (Forestry in Iceland.) Hedeselskabets Tidsskrift, Viborg 71: 47-59.

Mountain hemlock grows slowly but appears hardy in Iceland.

86. Flous, F.
1936. Révision du genre Tsuga. Toulouse Univ. Lab. Forest. Trav., tome 2, vol. 4, art. 3, 136 pp., illus. (Also: Toulouse Soc. d'Hist. Nat. Bul. 71: 315-450, illus. 1937.)

87. Forest Soils Committee of the Douglas-fir Region.
1957. An introduction to forest soils of the Douglas-fir region of the Pacific Northwest. Various paging, illus. Seattle: Univ. Wash.

"The distribution of this species [mountain hemlock] resembles that of Alaska cedar but is more abundant.... It occupies cold, humid, high altitude sites usually...is more abundant in British Columbia than in Oregon and Washington and occurs there at much lower elevations. Its ecological classification is not always clear; but towards the south, especially, it is usually considered climax. However, on Mt. Brenton on Vancouver Island, excellent stands of high vigor occur in the even-aged form as a result of fire."

88. Franklin, Jerry F.
1961. Seedling identification guide for 25 conifers of the Pacific Northwest.* U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 65 pp., illus.

Information on the seedling characteristics of mountain hemlock.

89. Furniss, R. L., and Dowden, P. B.
1941. Western hemlock sawfly, Neodiprion tsugae Middleton, and its parasites in Oregon. Jour. Econ. Ent. 34: 46-52.

Report of western hemlock sawfly attacking mountain hemlock.

90. Garman, E. H.
1953. Pocket guide to the trees and shrubs of British Columbia. Brit. Columbia Forest Serv. Pub. B. 28 (Ed. 2, rev.), 102 pp., illus.

91. Gilkey, Helen M., and Powell, Garland M.
1951. Handbook of Northwest flowering plants. Ed. 2, 412 pp., illus. Portland, Oreg.: Binfords & Mort.

92. Gill, L. S.
1935. Arceuthobium in the United States. Conn. Acad. Arts and Sci. Trans. 32: 111-245, illus.

Discusses characteristics of the genus, nomenclature, distribution, hosts, effects on forms of attacked trees, physiological relationships, economic importance, methods of control. A. campylopodum forma tsugensis has been collected on mountain hemlock at five locations in California, one in Idaho, and three in Oregon.

93. Gillett, George W., Howell, John Thomas, and Leschke, Hans.
1961. A flora of Lassen Volcanic National Park, California. Wasmann Jour. Biol. 19: 1-185, illus.

94. Gorman, M. W.
1907. Vegetation of the northeast slope of Mount Baker. Mazama 3: 31-48.

Mountain hemlock and Pacific silver fir are the most abundant species between 4,000 and 5,000 feet. Mountain hemlock, with whitebark pine and subalpine fir, occur above 5,500 feet to tree line at 6,700 feet.

95. _____
1920. The flora of Mount Hood. Oreg. Out-of-Doors 1: 64-96.

96. Graham, Donald P.
1959. Dwarfmistletoe survey in Coeur D'Alene National Forest.* U.S. Forest Serv. Intermountain Forest & Range Expt. Sta. Res. Note 68, 5 pp., illus.

97. Graham, R. D.
1956. The preservative treatment of eight Oregon conifers by pressure processes. Amer. Wood Preservers Assoc. Proc. 52: 118-139, illus.

98. _____ and Miller, D. J.
1958. Service life of treated and untreated fence posts on the T. J. Starker Post Farm.* Sup. to Oreg. State Forest Prod. Res. Center Prog. Rpt. 11, 4 pp.

99. Gratkowski, H. J.
1958. Natural reproduction of Shasta red fir on clear cuttings in southwestern Oregon. Northwest Sci. 32: 9-18, illus.

100. Gregory, R. A.
1957. 1956 cone crop report for Alaska tree species.* U.S. Forest Serv. Alaska Forest Res. Center Tech. Note 35, 2 pp., illus.

101. Hansen, Henry P.
1938. Pollen analysis of some interglacial peat from Washington. Univ. Wyo. Pub. 5: 11-18, illus.

102. _____
1941. Further pollen studies of post Pleistocene bogs in the Puget Lowland of Washington. Torrey Bot. Club Bul. 68: 133-148, illus.

"An interesting and important fact was learned recently concerning the pollen of mountain hemlock (Tsuga mertensiana). Pollen of this species collected on Mt. Rainier was found to have bladders, somewhat similar to that of pine, fir, and spruce. It may be differentiated from these species, however, because of the spheroidal cell and fine reticulum of the bladders. Through correspondence with Wodehouse after his examination of the pollen it was found that he had learned of the bladders on mountain hemlock after he published his book on pollen (1935). He refers to the presence of bladders on fossil hemlock pollen from the Eocene and Tertiary, some with and some without, and all gradations between. Pollen collected from presumably Tsuga mertensiana on the University of Washington campus at Seattle has no bladders, which may indicate a similar gradation for this species. A further check...must be made to verify or refute this possibility."

103. _____
1941. Paleoecology of a bog in the spruce-hemlock climax of the Olympic Peninsula. Amer. Midland Nat. 25: 290-297, illus.

104. _____
1941. Paleoecology of a montane peat deposit near Lake Wenatchee, Washington. Northwest Sci. 15: 53-65, illus.

105. _____
1941. Paleoecology of two peat deposits on the Oregon Coast. Oreg. State Col. Monog. Studies in Bot. 3, 31 pp., illus.

106. _____
1942. The influence of volcanic eruptions upon post-Pleistocene forest succession in central Oregon. Amer. Jour. Bot. 29: 214-219, illus.

107. Hansen, Henry P.
1942. A pollen study of lake sediments in the lower Willamette Valley of western Oregon. Torrey Bot. Club Bul. 69: 262-280, illus.

108. _____
1942. A pollen study of a montane peat deposit near Mount Adams, Washington. Lloydia 5: 305-313, illus.

109. _____
1942. Post-Mount Mazama forest succession on the east slope of the central Cascades of Oregon. Amer. Midland Nat. 27: 523-534, illus.

110. _____
1943. Paleoecology of a peat deposit in east central Washington. Northwest Sci. 17: 35-40, illus.

111. _____
1943. A pollen study of a subalpine bog in the Blue Mountains of northeastern Oregon. Ecol. 24: 70-78, illus.

112. _____
1943. A pollen study of two bogs on Orcas Island, of the San Juan Islands, Washington. Torrey Bot. Club Bul. 70: 236-243, illus.

113. _____
1943. Post-Pleistocene forest succession in northern Idaho. Amer. Midland Nat. 30: 796-802, illus.

114. _____
1947. Climate versus fire and soil as factors in postglacial forest succession in the puget lowland of Washington. Amer. Jour. Sci. 245: 265-286, illus.

115. _____
1947. Postglacial forest succession, climate, and chronology in the Pacific Northwest. Amer. Phil. Soc. Trans. (n.s.) vol. 37, pt. 1, 130 pp., illus.

This report is based on pollen analysis of sedimentary columns obtained from 55 areas in Oregon, Washington, and northern Idaho, and summarizes most of the preceding 14 references. Mountain hemlock is not very important in interpretation of postglacial forest succession except in the Oregon Cascades. Here, mountain hemlock pollen is most consistently and abundantly represented in the upper levels of the profiles. This follows the trend of western hemlock, true firs, and

Douglas-fir and supports evidence for increase in coolness and moisture in later postglacial time which has persisted to the present. There is no evidence that timberline species, including mountain hemlock, ever existed in greater abundance at lower elevations in early postglacial time than now.

116. Hansen, Henry P.
1948. Postglacial forests of the Glacier National Park region. Ecol. 29: 146-152, illus.

117. _____
1950. Pollen analysis of three bogs on Vancouver Island, Canada. Jour. Ecol. 38: 270-276, illus.

118. _____
1955. Postglacial forests in south central and central British Columbia. Amer. Jour. Sci. 253: 640-658, illus.

119. _____ and Mackin, J. Hoover.
1949. A pre-Wisconsin forest succession in the Puget lowland, Washington. Amer. Jour. Sci. 247: 833-855, illus.

120. Harlow, William M., and Harrar, Ellwood S.
1958. Textbook of dendrology. Ed. 4, 561 pp., illus. New York, London: McGraw-Hill Book Co., Inc.

121. Hayes, G. L.
1959. Forest and forest-land problems of southwestern Oregon.* U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 54 pp., illus.

The "true fir–mountain hemlock" type occupies 1,200 square miles of the higher Cascades in southwestern Oregon. It is considered worthy of intensive management and is important for water production. Mountain hemlock is a commercially important softwood in this region.

122. Hedgcock, George Grant.
1912. Notes on some diseases of trees in our national forests. II. Phytopath. 2: 73-80.

Mentions that mountain hemlock is attacked by Trametes pini, Polyporus schweinitzii, and Echinodontium tinctorium.

123. Hedgcock, George Grant.
1914. Notes on some diseases of trees in our national forests. IV. Phytopath. 4: 181-188.

Notes the occurrence of Herpotrichia nigra (a snow mold) on many species of conifers throughout the West, including mountain hemlock at Crater Lake. Also reports mountain hemlock as a host of Fomes pinicola.

124. _____
1915. Notes on some diseases of trees in our national forests. V. Phytopath. 5: 175-181.

125. Heintzleman, B. F.
1928. Pulp-timber resources of southeastern Alaska. U.S. Dept. Agr. Misc. Pub. 41, 34 pp., illus.

Discusses the physical characteristics of the region, timber resources, National Forest administration and policy, pulp industry potential, etc. "Mountain hemlock is largely confined to the higher altitudes.... It is largely inaccessible and is not important commercially ...quite similar to western hemlock in appearance, but is smaller... has more taper and is less clear of branches and knots."

126. Heller, A. A.
1909. The alpine spruce. Muhlenbergia 5: 105-108.

Heller argues against placing mountain hemlock in the genus Tsuga.

127. Heller, E.
1910. Partial list of plants, chiefly shrubs and trees. In Mammals of the 1908 Alexander Alaska Expedition. Univ. Calif. Pub. in Zool. 5: 349-360.

Describes the vegetation of the outer islands of Prince Williams Sound (these were different from those described by Cooper). Vegetation in this area is similar to that of southwestern Alaska. Spruce is the most abundant tree. Western hemlock is confined to the immediate vicinity of the coast. Mountain hemlock is almost as numerous as the spruce, and it has a universal distribution from the waterline to timberline.

128. Henry, Joseph Kaye.
1915. Flora of southern British Columbia and Vancouver Island, with many references to Alaska and northern species. 363 pp. Toronto: W. S. Gage.

129. Heusser, Calvin J.
1952. Pollen profiles from southeastern Alaska. Ecol. Monog. 22: 331-352, illus.

130. _____
1954. Additional pollen profiles from southeastern Alaska. Amer. Jour. Sci. 252: 106-119, illus.

131. _____
1954. Alpine fir at Taku Glacier, Alaska, with notes on its post-glacial migration to the territory. Torrey Bot. Club Bul. 81: 83-86, illus.

Isolated clumps of Krummholz mountain hemlock and alpine fir were found growing at 3,300 feet adjacent to Taku Glacier. Mountain hemlock in this area was in anthesis on July 9, 1952.

132. _____
1955. Pollen profiles from Prince William Sound and southeastern Kenai Peninsula, Alaska. Ecol. 36: 185-202, illus.

133. _____
1955. Pollen profiles from the Queen Charlotte Islands, British Columbia. Canad. Jour. Bot. 33: 429-449, illus.

134. _____
1957. Pleistocene and postglacial vegetation of Alaska and the Yukon territory. Oreg. State Col. Biol. Colloquium Proc. 18: 62-72, illus.

135. _____
1957. Variations of Blue, Hoh, and White Glaciers during recent centuries. Arctic 10: 139-150, illus.

136. _____
1960. Late-Pleistocene environments of North Pacific North America. Amer. Geog. Soc. Spec. Pub. 35, 308 pp., illus. New York: Amer. Geog. Soc.

Valuable source of information on the distribution of mountain hemlock along the North Pacific coast and its history during the late Pleistocene. Summarizes much of the information presented in the preceding seven references. Heusser describes the occurrence and general habits of mountain hemlock in south-central and southeastern Alaska, British Columbia, and on the Olympic Peninsula. His range map for mountain hemlock is the best available.

Pollen of mountain hemlock has a granulate exine and finely reticulated bladders and is 63 to 82 mu in overall length. It is easily identified.

In south-central and southeastern Alaska mountain hemlock pollen generally develops in greatest proportions in profiles after lodgepole pine, Sitka spruce, and western hemlock. Exceptions to this in south-central Alaska, Heusser ascribed to mountain hemlock's ability to survive climatic conditions more continental (less humidity and greater temperature extremes) than any of the other coastal conifers and pioneer sites before they could become important. In British Columbia mountain hemlock pollen is most prominent in higher elevation profiles although a brief prominence sometimes occurs in others, probably as a result of "local plant succession during the postglacial migration of hemlock up into the mountains." In a profile on the Olympic Peninsula a sharp prominence of pollen is attributed to the restriction of mountain hemlock to a refugium between the mountain front and the ocean as a result of glacial conditions.

A chronology of vegetation and environment during late Pleistocene for the various portions of the region is provided. Mountain hemlock is included in this chronology and contributes to its development. Glacial refugia, survival of plants (including mountain hemlock) on such refugia, and late-Pleistocene migrations are also considered.

137. Higinbotham, N., and Higinbotham, Betty Wilson.
1954. Quantitative relationships of terrestrial mosses with some coniferous forests at Mt. Rainier National Park. Butler Univ. Bot. Studies 11: 149-168.

Thirteen forest stands were included in this study of terrestrial mosses. These stands were classified into five climax communities. Mountain hemlock was found in the "Abies amabilis-Tsuga mertensiana community" which generally occurs at elevations of 4,000 to 5,000 feet. Both the shrub and herb vegetation and mosses were found to be quite distinctive in this community. Mountain hemlock was also found in the "Abies lasiocarpa community" which occurred at higher elevations. Complete species lists are included for the stands studied.

138. Hoffman, Bruce E.
1912. Sitka spruce of Alaska. Soc. Amer. Foresters Proc. 7: 226-238.

The forests of southeastern Alaska might be divided into three general types. In the upper-slope type at 1,200- to 2,400-foot elevation, western hemlock is gradually replaced by mountain hemlock. Sitka spruce and western redcedar are gradually eliminated and are nearly absent at the upper limit. In the timberline type above 2,400-foot elevation,

scrubby mountain hemlock predominates and is generally the only species present.

139. Hultén, Eric.
1941. Flora of Alaska and Yukon. I. Pteridophyta, Gymnospermae, and Monocotyledonae (Pandanale and Helobiae). Lunds Univ. Aarsskrift. N. F. Avd. 2, Bd. 37, Nr. 1, pp. 1-127, illus.

140. Hustich, Ilmari.
1953. The boreal limits of conifers. Arctic 6: 149-162, illus.

141. James, G. A.
1959. Seed production in a scrub stand.* U.S. Forest Serv. Alaska Forest Res. Center Tech. Note 43, 3 pp.

142. Jeffrey, Edward C.
1904. The comparative anatomy and phylogeny of the Coniferales. Pt. 2. The Abietineae. Mem. Boston Nat. Hist. 6: 1-37, illus.

143. Jepson, Willis Linn.
1909. A flora of California. Pt. 1. Pinaceae to Taxaceae. Pp. 33-64, illus. Berkeley: Univ. Calif. Students Co-op. Soc.

144. _____
1910. The silva of California. Calif. Univ. Mem. vol. 2, 480 pp., illus. Berkeley: The Univ. Press.

145. _____
1923. The trees of California. Ed. 2, 240 pp., illus. Berkeley: Sather Gate Book Shop.

146. _____
1923-25. A manual of the flowering plants of California. 1,238 pp., illus. Berkeley: Univ. Calif. Assoc. Students Store.

147. Johnson, L. P. V.
1939. A descriptive list of natural and artificial interspecific hybrids in North American forest-tree genera. Canad. Jour. Res. Sect. C. 17: 411-444.

148. Jones, George Neville.
1936. A botanical survey of the Olympic Peninsula, Washington. Univ. Wash. Pub. in Biol., vol. 5, 286 pp., illus.

Tsuga mertensiana is considered to be a characteristic tree and climax component of the Hudsonian zone forest in the Olympic Mountains.

149. Jones, George Neville.
1938. The flowering plants and ferns of Mount Rainier. Univ. Wash. Pub. in Biol., vol. 7, 192 pp., illus.

Jones decided there was an Abies-Tsuga-Chamaecyparis climax association in the Hudsonian zone. This zone was characterized by alpine fir, mountain hemlock, Alaska cedar, and whitebark pine, the first three being constituents of the climax.

150. Keen, F. P.
1952. Insect enemies of western forests. U.S. Dept. Agr. Misc. Pub. 273 [rev.], 280 pp., illus.

The main trunk of mountain hemlock is attacked by a bark beetle (Scolytus tsugae) and two borers. The wood is attacked by several species of Ambrosia beetles and borers, and smaller twigs, limbs, trunks by two borers, a twig beetle, and twig weevil. The bark beetle is the only insect of major importance.

151. _____
1958. Cone and seed insects of western forest trees. U.S. Dept. Agr. Tech. Bul. 1169, 168 pp., illus.

Insect damage appears to be light in mountain hemlock seeds although they are of very poor quality some years. Three species of insects which injure both cones and seeds and one species which damages seed only were collected and identified.

152. Kienholz, Raymond.
1930. The wood structure of a "pistol-butted" mountain hemlock. Amer. Jour. Bot. 17: 739-764, illus.

A detailed study of wood structure in a pistol-butted and straight mountain hemlock which were growing at 3,500-foot elevation in the southwestern Washington Cascades. Includes data on ring widths, summerwood percent, occurrence of compression wood, radial and tangential tracheid diameters, cell wall thickness, occurrence of medullary rays, and tracheid length.

153. Kimmey, James W.
1957. The dwarfmistletoes of California and their control.* U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Tech. Paper 19, 12 pp., illus.

Mountain hemlocks growing in California are attacked by western dwarfmistletoe (Arceuthobium campylopodum forma tsugensis). Characteristics of the Arceuthobium of California, symptoms of infection, damage done, control possibilities, recommended control procedures, and control costs are discussed.

154. Kirkwood, J. E.
1930. Northern Rocky Mountain trees and shrubs. 340 pp., illus. Stanford Univ.: Stanford Univ. Press.

155. Klyver, F. D.
1931. Major plant communities in a transect of the Sierra Nevada Mountains of California. Ecol. 12: 1-17, illus.

Describes two vegetational transects in the Mono Lake region. Vegetation areas include "fir-tamarack forest," "subalpine forest (west slope)," "subalpine forest (east slope)," and "alpine communities." Mountain hemlock, with whitebark pine and western white pine, characterizes the subalpine forest on the west slope. Whitebark pine is the only tree found on the east-slope subalpine forest.

156. Krajina, V. J.
1961. 1960 progress report on N.R.C. Grant No. T-92 entitled ecology of the forests of the Pacific Northwest.* Univ. Brit. Columbia Dept. Biol. and Bot., 62 pp., illus.

See abstract of next reference.

157. _____
1962. 1961 progress report on N.R.C. Grant No. T-92 entitled ecology of the forests of the Pacific Northwest.* Univ. Brit. Columbia Dept. Biol. and Bot., 37 pp., illus.

Brief review of some research presently in progress in British Columbia. Mountain hemlock is included in the studies of: "Plant communities of the Coastal Subalpine Zone in British Columbia"; "Ecotopes of plant communities of the Coastal Subalpine Zone in British Columbia"; and "Ecological studies in the subalpine-alpine ecotone of Garibaldi Park."

158. Krajina, Vladimir J.
1959. Bioclimatic zones in British Columbia. Univ. Brit. Columbia Bot. Ser. 1, 47 pp., illus.

A discussion of eight bioclimatic zones found in British Columbia. Lists of the climatic and edaphic climax vegetation (trees, shrubs, herbs, bryophytes, and lichens), as well as a listing of associated woody plants, discussion of general distribution, and data on the climate and typical soils are provided for each zone. Mountain hemlock is the major tree species in the climatic climax community of the "Subalpine Mountain Hemlock Zone"; it is called the "Tsuga mertensiana-Abies amabilis-Vaccinium alaskaense-Vaccinium membranaceum-Rubus pedatus" association. Mountain hemlock is also a minor species in the climatic climax of the "Subalpine Engelmann Spruce-Subalpine Fir Zone" and is a minor "associated woody plant" in the "Coastal Western Hemlock Zone."

159. Kuijt, Job.
1955. Dwarf mistletoes. Bot. Rev. 21: 569-627, illus.

160. _____
1960. The distribution of dwarf mistletoes, Arceuthobium, in California. Madrono 15: 129-139, illus.

Kuijt cites three specimens of Arceuthobium campylopodum collected on mountain hemlock in California and argues against basing a host form on the genus Tsuga.

161. Kurth, E. F.
1958. Chemical analysis of mountain hemlock. TAPPI 41(12): 733-734.

Chemical analysis of bark and wood of mountain hemlock.

162. Langille, H. D., Plummer, Fred G., Dodwell, Arthur, and others.
1903. Forest conditions in the Cascade Range Forest Reserve, Oregon. U.S. Geol. Survey Prof. Paper 9, 298 pp., illus.

163. Lawrence, Donald B.
1958. Glaciers and vegetation in southeastern Alaska. Amer. Scientist 46: 89-122, illus.

Relates the same vegetation successional sequence in this region that Cooper and others have up to the "climax forest" of western and mountain hemlocks and Sitka spruce. After this stage, according to Lawrence, the climax forest on many areas is slowly replaced by the formation of muskeg and pit ponds. He notes the establishment and slow growth of mountain hemlock (foot-tall specimens 75 years old) which sometimes become established on this climax muskeg. Lodgepole pine is the only conifer which can reach tree size on the muskeg.

164. _____ and Lawrence, Elizabeth G.
1959. Radiocarbon dating of some events on Mount Hood and Mount St. Helens. Mazama 40(14): 10-18, illus.

165. Leiberg, John B.
1900. Bitterroot Forest Reserve. U.S. Geol. Survey 20th Ann. Rpt. 1898-1899, Pt. 5, Forest Reserves: 317-410, illus.

Mountain hemlock extended southward into the northern portion of the reserve. Leiberg noted that suitable habitat occurred just beyond its range limits, yet there was no evidence it ever extended further south. Mountain hemlock was normally found in alpine-type forests, rarely below 5,500 and 6,500 feet on north and south slopes, respectively, and reached a maximum elevation of 8,000 to 9,000 feet. A range map and

detailed descriptions of local distribution are provided. Most mountain hemlock was old growth up to 600 years of age, 60 to 95 feet tall with 15 to 35 feet of clear trunk 3 to 6 feet in diameter, and about 30 percent defect due to rot. Second growth was 150 to 175 years of age, 30 to 75 feet tall with 15 to 30 feet of clear trunk, and 1 to 1-1/2 feet in diameter. It tended to form pure stands. Leiberg thought mountain hemlock succumbed readily to fire, slight scorching resulting in death. Cone and seed production was low, and a large percentage of ovules were aborted. Cones matured in August and scales opened readily; dispersion was slow and uncertain, however. Reproduction was deficient, mountain hemlock giving way to subalpine fir and Engelmann spruce, mainly because of fire. Leiberg considered its greatest value was for watershed protection, i.e., slowing spring snowmelt and runoff.

166. Leiberg, John B.
1900. Cascade Range Forest Reserve, Oregon, from Township 28 South to Township 37 South, inclusive; together with the Ashland Forest Reserve and adjacent forest regions from Township 28 South to Township 41 South, inclusive, and from Range 2 West to Range 14 East, Willamette Meridian, inclusive. U.S. Geol. Survey 21st Ann. Rpt. 1899-1900, Pt. 5, Forest Reserves: 209-498, illus.

Mountain hemlock was abundant at higher elevations in the Cascades and along the Rogue River-Umpqua River divide in this southern Oregon reserve, forming 6.5 percent of the forest on the west side and 1 percent on the east side of the Cascade divide. Commonly found at elevations of 6,200 to 9,200 feet, it attained best development between 5,900 and 7,000 feet. On small areas stands were composed entirely of mountain hemlock, and it formed 75 to 85 percent of extensive stands. Generally, the species ratio was due to chance; on a large area undisturbed by fire, Leiberg thought mountain hemlock would be preponderant. At timberline, whitebark pine was most important, usually the only species, but mountain hemlock predominated within a few hundred feet of this line. At high elevations mature mountain hemlock forests consisted of low, stunted, widely spaced trees; at middle elevations stands were open and parklike with groups of mountain hemlock interspersed with noble fir and western white pine. At the lowest elevations in the mountain hemlock zone, mature stands were "...magnificent examples of forest growth but little inferior in timber volume to the best stands of the red-fir type." These were of mountain hemlock and noble fir. Younger stands of mountain hemlock were "exceedingly close set" with 4,000 to 10,000 trees per acre in 20- to 40-year-old stands. Noble fir and mountain hemlock were giving way to lodgepole pine because of fires. Pure stands of mountain hemlock were characterized by associations of 10 to 25 individuals which "stand so close they apparently all spring from a common root." Leiberg thought this grouping the result of cone burial before opening and subsequent development of clumps of young seedlings

which eventually became grafted together at ground level. Mountain hemlock was sound even where the trees had attained a great age, provided fire had been excluded. It was considered quite susceptible to fire because of thin bark on most trees and because of the habit of growing in clumps.

167. Leiberg, John B.
1902. Forest conditions in the northern Sierra Nevada, California. U.S. Geol. Survey Prof. Paper 8, 194 pp., illus.

A report on the forest conditions between latitude 39° and 40° and longitude 120° and 121°31'. Mountain hemlock characterized the highest summits and slopes with an interrupted and uneven distribution. It was generally most abundant and best developed in the southern part of the region. Mountain hemlock was important in the "Shasta-fir" forest type, ranking fourth after Shasta fir, lodgepole pine, and western white pine; however, in the mountains south of Eureka Peak it formed stands which were 60 to 80 percent pure. No trees over 175 years of age were noted but Leiberg thought it should be long lived. In this region it was up to 24 to 26 inches in diameter at the base, usually less than 20 inches, and limby to the ground. Mountain hemlock sometimes occurred in dense, nearly pure stands of 4,000 to 5,000 stems per acre. It was increasing in numbers along the highest summits in its range and formed 60 to 75 percent of the new growth on some old burns. Leiberg thought extensions of its range were worthy of note because they seemed to coincide with lines of heaviest precipitation.

168. Lemmon, Robert S.
1951. Best loved trees of America. Home Gard. 17(6): 47-53, illus. (Also: Lemmon, Robert S. 1952. The best loved trees of America. 253 pp., illus. Garden City, N.Y.: Doubleday and Co., Inc.)

169. Little, Elbert L., Jr.
1953. Check list of native and naturalized trees of the United States (including Alaska). U.S. Dept. Agr. Handb. 41, 472 pp.

Correct botanical name for mountain hemlock is Tsuga mertensiana (Bong.) Carr. Its range is from southern Alaska (Cook Inlet) southeast through western British Columbia, Washington, and Oregon to central California and western Nevada; also, east to mountains of southeastern British Columbia, western Montana, northern Idaho, and northeastern Oregon. Western hemlock (Tsuga heterophylla (Raf.) Sarg.) was formerly known as Tsuga mertensiana.

170. Little, Elbert L., Jr.
1956. Contributions toward a flora of Nevada No. 40. Pinaceae, Rutaceae, Meliaceae, Anacardiaceae, Tamaricaceae, Cornaceae, Oleaceae, Bignoniaceae of Nevada.* U.S. Dept. Agr. Agr. Res. Serv. Plant Indus. Sta., 81 pp., illus.

171. Lutz, H. J.
1930. Observations on the invasion of newly formed glacial moraines by trees. Ecol. 11: 562-567, illus.

Pioneer tree species on glacial moraines in Prince William Sound are Sitka spruce, mountain hemlock, Sitka alder, and cottonwood in order of abundance. Layering was noted on a 3-inch d.b.h. mountain hemlock tree.

172. McAvoy, B.
1931. Ecological survey of the Bella Coola region. Bot. Gaz. 92: 141-171.

Mountain and western hemlocks grow together in the valleys and on the north-facing slopes. In the valley bottom western hemlock is the most common.

173. McGugan, B. M.
1958. Forest Lepidoptera of Canada recorded by the Forest Insect Survey. Vol. 1--Papilionidae to Arctiidae. Canada Dept. Agr. Pub. 1034, 76 pp., illus.

174. McMinn, Howard E., and Maino, Evelyn.
1947. An illustrated manual of Pacific Coast trees. Ed. 2, 409 pp., illus. Berkeley: Univ. Calif. Press.

175. Markwardt, L. J.
1930. Comparative strength properties of woods grown in the United States. U.S. Dept. Agr. Tech. Bul. 158, 8 pp.

176. _____
1931. The distribution and the mechanical properties of Alaska woods. U.S. Dept. Agr. Tech. Bul. 226, 80 pp., illus.

"Mountain hemlock is one of the few species in which shrinkage and the principal strength properties all closely and uniformly correspond to what would be expected for its density." Tabulated data on strength properties. Mountain hemlock was rated moderate in all respects.

177. Markwardt, L. J., and Wilson, T. R. C.
1935. Strength and related properties of woods grown in the United States. U.S. Dept. Agr. Tech. Bul. 479, 99 pp., illus.

Includes tabulated data on the strength and other wood properties of mountain hemlock. Wood from 10 trees grown in two different localities--Alaska and Montana--was tested. Information is provided on rings per inch, summerwood percent, moisture content, specific gravity, weight, shrinkage, maximum tensile strength, and results of static bending, impact bending, compression, hardness, shear, and cleavage tests.

178. Martin, J. S.
1949. Sulphate pulping of logging and sawmill wastes of old-growth Douglas fir and of certain associated species. TAPPI 32(12): 534-539.

In pulping experiments carried out with Douglas-fir wastes, mountain hemlock, noble fir, and lodgepole pine, all species were pulped satisfactorily with normal amounts of chemicals. The three latter species produced pulp with excellent bursting and fair tearing strengths. Pulp from 70 percent Douglas-fir and 10 percent of each of the other three species had good bursting and excellent tear strength and was of higher quality than pulps from sound Douglas-fir alone. Includes information on chemical and physical tests of mountain hemlock, noble fir, and lodgepole pine woods. (Also reported in U.S. Forest Serv. Forest Prod. Lab. Rpt. 1747.)

179. Merriam, C. Hart.
1899. Results of a biological survey of Mt. Shasta, California. U.S. Bur. Biol. Survey North Amer. Fauna 16, 179 pp., illus.

The range of mountain hemlock is greatly restricted on Mt. Shasta. It is confined mainly to narrow strips along streams or gulches or to tongues along the east sides of buttes and ridges. Best development is in the lower Hudsonian zone (7,200- to 8,000-foot elevation). It reaches a maximum elevation of 8,700 feet, about 1,000 feet less than the maximum attained by whitebark pine. Generally, its distribution furnishes an index to areas of greater soil moisture. Mature mountain hemlocks are 80 to 100 feet tall and up to 6 feet in diameter. They often occur in clusters of three to seven and form a "dark and somber" forest which has few associated shrubs or herbs. Merriam noted that mountain hemlock is a prolific seeder and cones form an important part of the litter.

180. Mosher, Milton M., and Lunnum, Knut.
1956. Trees of Washington. Wash. State Col. Inst. Agr. Sci. Ext. Serv. Bul. 440 [rev.], 40 pp., illus.

181. Muenscher, W. C.
1941. The flora of Whatcom County, State of Washington. 134 pp., illus. Ithaca, N.Y.

182. Munns, E. N.
1938. The distribution of important forest trees of the United States. U.S. Dept. Agr. Misc. Pub. 287, 176 pp., illus.

183. Munz, Philip A., and Keck, David D.
1949. California plant communities. El Aliso 2: 87-105, illus.

Mountain hemlock is a constituent of the lodgepole pine forest and subalpine forest communities in the montane coniferous forest vegetation type of the Sierran biotic province. Data are provided on the distribution, climate, and physiognomy of these communities.

184. _____ and Keck, David D.
1959. A California flora. 1,681 pp., illus. Berkeley: Univ. Calif. Press.

185. Noelle, W.
1910. Studien zur vergleichenden Anatomie und Morphologie der Koniferenwurzeln mit Rücksicht auf die Systematik. Bot. Zeitung 68(pt. 1): 169-266, illus.

Information on the anatomy and morphology of mountain hemlock roots.

186. Olson, D. S.
1959. Identification of coniferous seedlings in the northern Rocky Mountains.* Univ. Idaho Forest Wildlife & Range Expt. Sta. Res. Note 15, 4 pp., illus.

A key for the identification of recently germinated seedlings, including mountain hemlock.

187. Oosting, H. J., and Billings, W. D.
1943. The red fir forest of the Sierra Nevada: Abietum magnificae. Ecol. Monog. 13: 259-274, illus.

A study of the California red fir forests of central and northern California. Includes information on the climate, geology, soils, and vegetation. Of 16 stations studied, mountain hemlock was present at 9 of the generally higher elevation stations. Vegetational analyses were made of five stations, one of which included mountain hemlock. At this station it was represented almost exclusively in the smallest size class--under 1.0 inch d.b.h. and one-half meter high. Mountain hemlock seemed to be a more characteristic red fir associate at higher elevations

and a minor, but fairly constant part of the Abies magnifica union. The red fir forest was considered to be a true climax at medium-high elevations in the Sierra Nevada with a vegetational constitution adapted to wet winters with heavy snowfall and to a short, dry, cool growing season.

188. Osgood, W. H.
1901. Natural history of the Cook Inlet region, Alaska. U.S. Bur. Biol. Survey North Amer. Fauna 21: 51-87, illus.

Mountain hemlock is the most abundant tree from the seacoast to timberline at Turnagain Arm. It is not found elsewhere in the Cook Inlet region, where it grows in association with white and Sitka spruce.

189. _____
1901. Natural history of the Queen Charlotte Islands. U.S. Bur. Biol. Survey North Amer. Fauna 21: 7-50, illus.

Mountain hemlock is found only in the mountains near the head of Cumshewa Inlet where it appears with Alaska cedar at about 2,000-foot elevation and persists to tree line.

190. Paul, Benson H.
1959. The effect of environmental factors on wood quality.* U.S. Forest Serv. Forest Prod. Lab. Rpt. 2170, 48 pp.

Mountain hemlock has slower growth and denser wood than the other hemlock species. The average of 41 tests made of mountain hemlock wood indicates a specific gravity of 0.46, a value equal to that for Douglas-fir. Twelve percent of the wood tested had 11 to 15 rings per inch (sp.gr. 0.46), 24 percent had 16 to 20 rings per inch (sp.gr. 0.43), and 64 percent had 21 rings or over per inch (sp.gr. 0.47). Under management a growth rate of 10 rings per inch, if obtainable, should maintain specific gravity at a satisfactory level.

191. Payne, Doris.
1944. My friends, the hemlocks of Crater Lake. Amer. Forests 50: 376-379, 415, illus.

192. Peattie, Donald Culross.
1953. A natural history of western trees. 751 pp., illus. Boston: Houghton Mifflin Co.

193. Peck, Morton Eaton.
1961. A manual of the higher plants of Oregon. Ed. 2, 936 pp., illus. Portland, Oreg.: Binfords and Mort.

194. Penhallow, David Pearce.
1907. A manual of the North American Gymnosperms. 374 pp., illus. Boston: Ginn & Co.

Includes information on the minute wood anatomy of mountain hemlock. Describes transverse, radial, and tangential views, discusses appearance and occurrence of tracheids, bordered pits, medullary rays, wood parenchyma, and resin ducts.

195. Piper, Charles V.
1906. Flora of the State of Washington. Contrib. U.S. Natl. Herb., vol. 11, 637 pp., illus.

196. _____ and Beattie, R. Kent.
1915. Flora of the northwest coast, including the area west of the summit of the Cascade Mountains, from the forty-ninth parallel south to the Calapooya Mountains on the south border of Lane County, Oreg. 418 pp., Lancaster, Pa.: Press of the New Era Printing Co.

197. Plummer, Fred G.
1900. Mount Rainier Forest Reserve, Washington. U.S. Geol. Survey 21st Ann. Rpt. 1899-1900, Pt. 5, Forest Reserves: 81-143, illus.

Mountain hemlock was found from 3,500 to 7,500 feet in elevation in this southern Washington reserve. The largest trees were 3 feet in diameter and 125 feet tall. The largest and heaviest stands, sometimes pure over limited areas, were found at 6,000 feet near Jennies Peak. Age determinations made of two trees--17-1/2 and 15-1/2 inches in diameter--indicated ages of 176 and 148 years. Mountain hemlock was noted as being able to resist fire better than other species in the "alpine zone."

198. _____
1902. Forest conditions in the Cascade Range, Washington, between the Washington and Mount Rainier Forest Reserves. U.S. Geol. Survey Prof. Paper 6, 42 pp., illus.

The area covered by this report was Ts. 19 to 28 N. and R. 9 E. to Columbia River. Plummer compared the distribution of species by zones at latitude 45°30' with their distribution at 47°30'. At the first locale, mountain hemlock occurred in the "whitebark pine zone" (6,000 to 7,000 feet or timberline), with whitebark pine, creeping juniper, and alpine larch. At latitude 47°30' it occurred in the "subalpine fir zone" (5,000 to 6,000 feet) with alpine fir. An altitudinal range and development diagram showed that Patton hemlock grew from 2,600 to 7,200 feet in elevation and reached maximum development at about 3,800 to 4,400 feet.

199. Plummer, Fred G.
1912. Lightning in relation to forest fires. U.S. Dept. Agr. Forest Serv. Bul. 111, 39 pp., illus.

200. Pratt, M. B.
1907. California red fir in the Tahoe Forest Reservation. Forestry Quart. 5: 159-165.

201. Prebble, M. L., and Graham, K.
1945. The current outbreak of defoliating insects in coast hemlock forests of British Columbia. Pt. 1. Description of outbreak and damage. Brit. Columbia Lumberman 29(2): 25-27, 42, 44, 46, 48, illus.

A discussion of the importance of the black-headed budworm, hemlock looper, hemlock sawfly, and western rusty tussock moth in the hemlock forests of British Columbia. Annual radial increment of mountain hemlock in two localities is shown for two decades and discussed in relation to years of insect defoliation.

202. Preston, Richard J., Jr.
1947. Rocky Mountain trees. Ed. 2, 285 pp., illus. Ames: Iowa State Col. Press.

203. _____
1961. North American trees (exclusive of Mexico and tropical United States). Ed. 2, 395 pp., illus. Ames: Iowa State Col. Press.

204. Randall, Warren R.
1957. Manual of Oregon trees and shrubs. 234 pp. Corvallis: Oreg. State Col. Coop. Assoc.

205. Rehder, Alfred.
1940. Manual of cultivated trees and shrubs hardy in North America. Ed. 2, 996 pp., illus. New York: The Macmillan Co.

206. Rhoads, Arthur S.
1923. The formation and pathological anatomy of frost rings in conifers injured by late frosts. U.S. Dept. Agr. Dept. Bul. 1131, 16 pp., illus.

Describes occurrence and appearance of "frost rings" in wood of several conifers including mountain hemlock. These rings were found in plants which appeared outwardly normal and in those with an abnormal compact bushy form (due to frost damage).

207. Rhoads, Arthur S., Hedgcock, George G., Bethel, Ellsworth, and Hartley, Carl.
1918. Host relationships of the North American rusts, other than gymnosporangiums, which attack conifers. Phytopath. 8: 309-352.

Lists leaf rust (Uredo holwayi) which attacks mountain hemlock.

208. Rigg, George B.
1914. Notes on the flora of some Alaskan sphagnum bogs. Plant World 17: 167-182, illus.

209. _____
1937. Some raised bogs of southeastern Alaska with notes on flat bogs and muskegs. Amer. Jour. Bot. 24: 194-198, illus.

210. _____
1958. Peat resources of Washington. Wash. State Div. Mines and Geol. Bul. 44, 272 pp., illus:

Discussion of Verlot peat area, Snohomish County (p. 188): "... The trees in the [peat] bogs were western white pine and mountain hemlock. The pines ranged in height from 1 foot or less up to 10 feet or more. The hemlocks ranged from 1 to 30 feet or more in height, and there were many larger dead conifers which were apparently of this species."

211. Riggs [Rigg], George B.
1925. Some sphagnum bogs of the North Pacific coast of America. Ecol. 6: 260-278, illus.

212. Roach, Archibald W.
1952. Phytosociology of the Nash Crater lava flows, Linn County, Oregon. Ecol. Monog. 22: 169-193, illus.

A phytosociologic study of several communities developing on a series of young volcanic substrates. The study area is at an elevation of 3,200 to 4,200 feet in the headwaters of the McKenzie River, central Oregon Cascades. Mountain hemlock was represented in three of the six associations delineated. In a Douglas-fir—alpine fir association, found on a block basalt substrate (with some scoria mixed in the broken crust), mountain hemlock occurs mainly as small seedlings on duff accumulations in patches of subalpine fir. A Douglas-fir—grand fir association occupies grayer, rounded block basalts mixed with a high proportion of volcanic sand and ash, and the scoria cones--the most mesic sites in the study area. Mountain hemlock is found at higher elevations in this association on the scoria slopes of Nash Crater. Although it makes up only 1 percent of the basal area in this community,

it is present in most size classes. A lodgepole pine association is found on ash and lapilli flats which are very xeric because of the deep, very porous ash and lapilli mantle. Mountain hemlock is encountered occasionally in this community (probably on scattered monadnocks of lava which protrude through the mantle of ash).

213. Ross, Charles R.
1957. Trees to know in Oregon. Oreg. State Col. Ext. Serv. Bul. 697 [rev.], 88 pp., illus. Corvallis: Oreg. State Col. Press.

214. Rowe, J. S.
1959. Forest regions of Canada. Canada Dept. North. Affairs and Nat. Resources Forestry Branch Bul. 123, 71 pp., illus. (Revision of "A forest classification for Canada," by W. E. D. Halliday. Canada Dept. North. Affairs and Nat. Resources Bul. 89. 1937.)

Mountain hemlock is represented in the "Interior Subalpine Section" (SA. 2) and "Coastal Subalpine Section" (SA. 3) of the "Subalpine Forest Region" and in the "Queen Charlotte Islands Section" (C. 4) of the "Coast Forest Region."

215. Rudinsky, J. A., and Vité, J. P.
1959. Certain ecological and phylogenetic aspects of the pattern of water conduction in conifers. Forest Sci. 5: 259-266, illus.

Tsuga mertensiana has a water-conducting system characterized by sectorial, winding ascent; that is, dye injected into the tree ascends in a sector, the stained sector winding around the tree axis as the distance from point of injection increases. Although this system would appear to limit the distribution of transpirational water, dye injections indicate that early springwood deviates to the left of late springwood and summerwood. This results in a larger "circo-lateral" portion of the growth ring being supplied from each root than would occur in a sapwood with parallel run of the tracheidal conduits. This, together with the winding of tracheidal conduits around the stem axis, may provide flexibility in response to environmental changes.

216. Rydberg, P. A.
1915. Phytogeographical notes on the Rocky Mountain region. IV. Forests of the subalpine and montane zones. Torrey Bot. Club Bul. 42: 11-25.

Information on the distribution of mountain hemlock in the northern Rockies.

217. Rydberg, P. A.
1916. Phytogeographical notes on the Rocky Mountain region. VI. Distribution of subalpine plants. Torrey Bot. Club Bul. 43: 343-364.

Mountain hemlock was grouped among "Species common to the northern Rockies and the Cascade Mountains," although Rydberg thought it belonged to the "Cascade element" of this common flora.

218. _____
1917. Phytogeographical notes on the Rocky Mountain region. VII. Formations in the subalpine zone. Torrey Bot. Club Bul. 44: 431-454.

219. _____
1922. Flora of the Rocky Mountains and adjacent plains. Ed. 2, 1,143 pp. (Reprinted 1954, New York: Hafner Pub. Co.)

220. St. John, Harold, and Hardin, Edith.
1929. Flora of Mt. Baker. Mazama 11: 52-102, illus.

221. _____ and Warren, Fred A.
1937. The plants at Mount Rainier National Park, Washington. Amer. Midland Nat. 18: 952-985.

222. Sargent, Charles Sprague.
1908. The silva of North America. Vol. 12. 144 pp., illus. Boston, New York: Houghton Mifflin Co.

A good dendrological reference, despite its age, with a botanical description and excellent drawings of leaves, cones, seed, cone scales, etc. Notes that the largest tree on record is a specimen 19 feet 7 inches in circumference at breast height growing in the California Sierras at 9,250 feet; erect cones may be found on trees growing slowly in exposed situations because of the thick, short, lateral branchlets on which they are growing; the "noblest forest" of mountain hemlock was found in the Crater Lake area; Sargent found mountain hemlock growing on the east slope of the Cascades near the Great Northern Cascade tunnel at an elevation of 2,200 feet; mountain hemlock was discovered on Baranoff Island near Sitka, Alaska, in 1827 by K. H. Mertens.

223. _____
1922. Manual of the trees of North America (exclusive of Mexico). Ed. 2, 910 pp., illus. Boston, New York: Houghton Mifflin Co. (Reprinted 1961, New York: Dover Publications, Inc.)

224. Schmidt, R. L.
1957. Climate and the altitudinal distribution of conifers. In Brit. Columbia Forest Serv. Forest Res. Rev. year ended March, 1957, p. 14.

225. _____
1957. The silvics and plant geography of the genus Abies in the coastal forests of British Columbia. Brit. Columbia Forest Serv. Tech. Pub. T. 46, 31 pp., illus.

226. _____
1958. Climate and the altitudinal distribution of conifers. In Brit. Columbia Forest Serv. Forest Res. Rev. year ended March, 1958, pp. 18-19.

227. _____
1960. Climate and the altitudinal distribution of conifers. In Brit. Columbia Forest Serv. Forest Res. Rev. year ended March, 1960, pp. 15-18, illus.

Progress report on a study being conducted to determine the relationships between climate and elevation and their direct and indirect influences upon the distribution and performance of several tree species, including mountain hemlock. Mountain hemlock pollen has been collected in quantity at the valley-bottom station indicating downhill transfer of pollen. (The study is being conducted in Elk Valley on Vancouver Island. Mountain hemlock occurs from 2,300-foot elevation to absolute tree line in this area.)

228. _____
1961. Climate and the altitudinal distribution of conifers. In Brit. Columbia Forest Serv. Forest Res. Rev. year ended March, 1961, pp. 11-13.

229. Schubert, G. H.
1952. Germination of various coniferous seeds after cold storage.* U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Forest Res. Note 83, 7 pp.

Two lots of mountain hemlock seed stored between 11 and 20 years at 41° F. in an airtight container had 0- and 2-percent germination. Seed stored for 21+ years had no germination. (Reported in less detail in Jour. Forestry 52: 446-447.)

230. Schubert, Gilbert H., and Baron, Frank J.
1959. California cone crop--1959.* U.S. Forest Serv. Pac. SW. Forest & Range Expt. Sta. Res. Note 155, 6 pp., illus.

231. Schubert, Gilbert H., and Baron, Frank J.
1960. California cone crop--1960.* U.S. Forest Serv. Pac. SW. Forest & Range Expt. Sta. Res. Note 164, 7 pp., illus.

232. Scott, David R. M.
1962. The Alaska region. In Regional silviculture of the United States, ed. by John W. Barrett. Pp. 571-591, illus. New York: The Ronald Press Co.

233. _____
1962. The Pacific Northwest region. In Regional silviculture of the United States, ed. by John W. Barrett. Pp. 503-570, illus. New York: The Ronald Press Co.

A discussion of the major forest types and growth rates, rotation ages, silvicultural practices, and damaging agents for each. Mountain hemlock replaces western hemlock at higher elevations in the Pacific silver fir-hemlock type which is a climax type group on the west side of the Cascade Range in the Canadian zone. The mountain hemlock-subalpine fir cover type (climax) is considered typical of protected locations or lower elevations in the Hudsonian zone of the Cascades.

234. Shacklette, Hansford T.
1962. Biotic implications of Alaskan biogeochemical distribution patterns. Ecol. 43: 138-139.

235. Shaw, Charles Gardner.
1958. Host fungus index for the Pacific Northwest. I. Hosts. Wash. Agr. Expt. Sta. Sta. Cir. 335, 127 pp.

A very complete listing of saprophytic and parasitic fungi known to occur on mountain hemlock.

236. Shaw, C. H.
1916. Vegetation of the Selkirks. Bot. Gaz. 61: 477-494, illus.

The forest vegetation was divided into two zones. Mountain hemlock was a principal species in the "Montane Zone."

237. Sherrard, E. C., and Davidson, P. B.
1928. The tannin content of Alaskan mountain hemlock bark (Tsuga mertensiana). Jour. Amer. Leather Chem. Assoc. 23: 371.

238. Sigafoos, Robert S.
1958. Vegetation of northwestern North America, as an aid in interpretation of geologic data. U.S. Geol. Survey Bul. 1061-E: 165-185, illus.

239. Sîlen, Roy R., and Woike, Leonard R.
1959. The Wind River Arboretum from 1912 to 1956.* U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Paper 33, 50 pp., illus.

The two native hemlocks, western and mountain, are the best of the five Tsuga species represented in this southwestern Washington arboretum. Mountain hemlock, although slow growing (growth index 0.41 compared with indigenous Douglas-firs), is the "handsomest and hardiest" of the hemlocks.

240. Smiley, F. J.
1915. The alpine and subalpine vegetation of the Lake Tahoe region. Bot. Gaz. 59: 265-286, illus.

Mountain hemlock is a principal tree of the Hudsonian zone in this area. Mountain hemlock stands are found chiefly on Lucile Ridge and in Desolation Valley.

241. Smiley, Frank Jason.
1921. A report on the boreal flora of the Sierra Nevada of California. Univ. Calif. Pub. Bot. 9: 1-423, illus.

A working flora for the high Sierra. Mountain hemlock is a Hudsonian zone indicator and is most abundant on windward slopes because of moisture requirements. Pure forests of this species are dark and damp with a brush-free forest floor. Mountain hemlock is frequently found along the line of seep-water emergence at foot of talus slopes in Tahoe region.

242. Society of American Foresters Committee on Forest Types.
1954. Forest cover types of North America (exclusive of Mexico). 67 pp., illus. Washington, D.C.: Soc. Amer. Foresters.

Mountain hemlock is a major component of the "Mountain hemlock–subalpine fir" and "Pacific silver fir–mountain hemlock" types. It is a minor component in the "white spruce–birch," "Engelmann spruce–subalpine fir," "red fir," "whitebark pine," "western hemlock," and "Jeffrey pine" types.

243. Somerville, William.
1916. Abnormal wood in conifers. Quart. Jour. Forestry 10: 132-136, illus.

244. Srivastava, L. M., and Esau, K.
1961. Relation of dwarfmistletoe (Arceuthobium) to the xylem tissue of conifers. I. Anatomy of parasite sinkers and their connection with host xylem. Amer. Jour. Bot. 48: 159-167, illus.

Anatomy of sinkers (radially orientated strands in the secondary phloem and wood of the host) of Arceuthobium in mountain hemlock and six other conifer species.

245. _____ and Esau K.
1961. Relation of dwarfmistletoe (Arceuthobium) to the xylem tissue of conifers. II. Effect of the parasite on the xylem anatomy of the host. Amer. Jour. Bot. 48: 209-215, illus.

Report continues from the previous reference. The most pronounced changes in xylem anatomy concerned the size and shape of infected rays. Because of the presence of the parasite tissue, the rays assumed a hypertrophied appearance; moreover, they fuse to form large composite rays, which involves intrusive growth of ray cells and displacement of fusiform initials. Rays increase in number in infected wood of mountain hemlock, and resin canals were observed although normally hemlock has no resin canals.

246. Stein, William I.
1954. Natural reproduction of Shasta red fir from a single good cone crop.* U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 100, 5 pp., illus.

247. Struble, George R.
1957. The fir engraver. A serious enemy of western true firs. U.S. Dept. Agr. Prod. Res. Rpt. 11, 18 pp., illus.

248. Sudworth, George B.
1897. Nomenclature of the arborescent flora of the United States. U.S. Dept. Agr. Div. Forestry Bul. 14, 417 pp.

249. _____
1900. Stanislaus and Lake Tahoe Forest Reserves, California, and adjacent territory. U.S. Geol. Survey 21st Ann. Rpt. 1899-1900, Pt. 5, Forest Reserves: 499-561, illus.

Mountain hemlock was strictly a subalpine tree confined chiefly to north slopes between 6,900- and 9,400-foot elevation, and most abundant between 7,000 and 8,500 feet. It was associated with lodgepole pine, western white pine, California red fir, and whitebark pine, and formed 10 to 25 percent of the stands. The tree trunks were never quite straight, generally strongly conical, and bore branches almost to the

ground. Tree heights were from 25 to 90 feet and diameters from 12 to 32 inches. The largest mountain hemlocks of the open forests were often uprooted by winds which may have accounted for the general absence of old trees in that forest type. Mountain hemlock reproduced plentifully throughout most of its range except at the upper altitudes. Numerous seedlings and young trees were present everywhere among the older trees. Old and even half-grown trees bore large crops of cones and an abundance of seed.

250. Sudworth, George B.
1908. Forest trees of the Pacific slope. U.S. Dept. Agr., 441 pp., illus.

Information on botanical characteristics, general growth, habits, and silvics of mountain hemlock in the Pacific Coast region. Includes a general range description and notes on local observations of the species.

251. _____
1918. Miscellaneous conifers of the Rocky Mountain region. U.S. Dept. Agr. Bul. 680, 45 pp., illus.

Information on botanical characteristics, general growth habits, and silvics of mountain hemlock in the Rocky Mountains. Includes a general range description, notes on local observations, and a distribution map of the species.

252. _____
1927. Check list of the forest trees of the United States, their names and ranges. U.S. Dept. Agr. Misc. Cir. 92, 295 pp.

253. Suksdorf, William N., and Howell, Thomas.
1896. Flora of Mount Adams. Mazama 1: 68-97.

254. Swedberg, Kenneth C.
1961. The coniferous ecotone of the east slope of the northern Oregon Cascades. Unpublished Ph. D. thesis on file Oregon State University, 118 pp., illus.

A study of the vegetation along an 18-mile transect from the fir-hemlock forests near the summit of the Cascades east to the juniper-sagebrush areas. Mountain hemlock occurs between 4,100- and 6,000-foot elevation. It is the most important tree species in the 5,400- to 6,000-foot zone where it grows with subalpine fir and whitebark pine. The densest stands in this zone are composed of mountain hemlock which have a meager ground flora and a few scattered tree seedlings. The trees are typically clumped in groups of three to eight, probably due to the "black-body" effect of the tree trunks on snowmelting. Mountain hemlock is invading many of the smaller openings and appears to be the

species most capable of recovering from snow-creep damage when growing in such locations. Mountain hemlock also occurs in some timber "atolls" in association with alpine fir, whitebark pine, and dwarf juniper, and in open stands on rocky ridges near the crest of the Cascades. In a lower zone, 5,000- to 5,400-foot elevation, the arborescent vegetation is largely mature lodgepole pine forest. Large numbers of mountain hemlock and alpine fir seedlings are present, however, and, together with grand fir, will probably form the climax stand on these sites.

255. Taylor, Raymond F.
1932. The successional trend and its relation to second-growth forests in southeastern Alaska. Ecol. 13: 381-391, illus.

256. _____ and Little, Elbert L., Jr.
1950. Pocket guide to Alaska trees. U.S. Dept. Agr. Handb. 5, 63 pp., illus.

Describes mountain hemlock in Alaska. "...small or medium-sized tree...from 30 to 60 feet tall and 10 to 20 inches in diameter, with marked taper, and with horizontal or drooping branches. It uncommonly reaches a height of 100 to 125 feet and a diameter of 30 to 40 inches at Prince William Sound. It grows in low muskegs, as well as on alpine slopes on the ocean side of the Coast Range in southeast Alaska where it reaches an altitude of 3,000 to 3,500 feet, higher than other trees, and becomes a prostrate shrub.... In the Prince William Sound and Cook Inlet regions it is found on better drained slopes and near tidewater, partly losing its dwarfed appearance."

257. Taylor, Walter P.
1922. A distributional and ecological study of Mount Rainier, Washington. Ecol. 3: 214-236, illus.

258. Thomas, G. P.
1958. Studies in forest pathology. XVIII. The occurrence of the Indian paint fungus, Echinodontium tinctorium E. & E., in British Columbia. Canada Dept. Agr. Forest Biol. Lab. Pub. 1041, 30 pp., illus.

A detailed study of the habitats, hosts, and frequency of occurrence of Indian paint fungus. Because the distribution pattern of the fungus did not fit a concept of geographical limits, it was studied on various habitat or "site types" classified on the basis of floristic structure and certain similarities in the conditions of the habitat. The study showed that susceptible species are attacked severely only on some habitats. Mountain hemlock occurs on 12 of the 50 habitat types delimited and is attacked by Indian paint fungus on 5 of these. Frequency of infection is abundant on one of the habitat types, infrequent on one, and rare on three. E. tinctorium was not observed on mountain hemlock

in coastal forests and reaches its maximum development on this species in the southeast-interior region.

259. Tidestrom, Ivar.
1925. Flora of Utah and Nevada. Contrib. U.S. Natl. Herb. vol. 25, 665 pp., illus.

260. Trappe, James M.
1960. Some probable mycorrhizal associations in the Pacific Northwest. II. Northwest Sci. 34: 113-117.

An association, probably mycorrhizal, was noted between Boletus frustosus Snell and Dick and mountain hemlock in Crater Lake National Park, Oregon. All specimens were found above 6,000-foot elevation in pure stands of mountain hemlock. One was found at 7,400-foot elevation--600 feet above timberline--arising from a mycorrhiza cluster of a shrubby mountain hemlock growing in a soil pocket on exposed talus.

261. Troll, C.
1955. Der Mount Rainier und das mittlere Cascaden-gebirge. Erdkunde 9: 264-274, illus.

262. U.S. Bureau of Entomology and Plant Quarantine.
1953. The more important forest insects in 1952--a summary. Div. Insect Detection and Ident. Coop. Econ. Insect Rpt. 3: 265-278.

263. U.S. Forest Service.
1948. Woody-plant seed manual. U.S. Dept. Agr. Misc. Pub. 654, 416 pp., illus.

Cones of mountain hemlock ripen in September and seed is dispersed in September and October. Minimum commercial seed-bearing age is 20 years. Of seed tested, six lots averaged 114,000 seeds per pound (range from 60,000 to 208,000) and 83-percent purity. A stratification period of 90 days in moist sand at 41° F. and germination temperatures of 68° (night) and 86° (day) are recommended. Four lots of seed tested for germination averaged 47 percent (range 1 to 78 percent).

264. _____
1955. Annual report 1954.* Alaska Forest Res. Center Sta. Paper 2, 35 pp., illus.

Frequency distribution curves for diameter classes illustrate the tolerant nature of mountain and western hemlock compared to western redcedar in southeastern Alaska stands.

265. U.S. Forest Service.
[1956.] Alaska forest research. Problems and present status. Annual report--1955.* Alaska Forest Res. Center Sta. Paper 4, 42 pp., illus.

Included in the discussion of the black-headed budworm survey: "...heavier defoliation at timberline has been observed to cause little damage and no top killing to either western or mountain hemlock...."

266. _____
1959. Annual report, 1958.* Pac. NW. Forest & Range Expt. Sta., 94 pp., illus.

Mountain hemlock appears highly susceptible to Poria weirii root rot. Characteristic infection centers, with severe damage, have been found in mountain hemlock types.

267. University of British Columbia Forest Club.
1959. Forestry handbook for British Columbia. Ed. 2, 800 pp., illus. Vancouver, B.C.: Univ. Brit. Columbia Forest Club.

268. Vabre-Durrieu, A.
1954. L'hybride Tsugo-Picea hookeriana et ses parents. Étude chromosomique et caryologique. (The hybrid Tsugo-Picea hookeriana and its parents. A cytological and caryological study.) Toulouse Univ. Lab. Forest. Trav., tome 1, vol. 5, art. 17, 4 pp., illus. (Also: Toulouse Soc. d'Hist. Nat. Bul. 89: 401-405, illus. 1954.)

Chromosome number of the supposed hybrid was found to be 2n = 24.

269. _____
1954. L'hybride Tsugo-Picea hookeriana et ses parents. Étude des plantules. (The hybrid Tsugo-Picea hookeriana and its parents. A study of the seedlings.) Toulouse Univ. Lab. Forest. Trav., tome 1, vol. 5, art. 15, 8 pp., illus. (Also: Toulouse Soc. d'Hist. Nat. Bul. 89: 47-54, illus. 1954.)

The author felt a study of the seedlings confirmed mountain hemlock is a hybrid of western hemlock and Sitka spruce.

270. _____
1956. Le froid et les graines de quelques Abiétacées. (The reaction to cold of seed of some species of Abietineae.) Toulouse Univ. Lab. Forest. Trav., tome 1, vol. 5, art. 29, 6 pp., illus. (Also: Toulouse Soc. d'Hist. Nat. Bul. 91: 113-118, illus. 1956.)

271. Van Dersal, William R.
1938. Native woody plants of the United States, their erosion-control and wildlife values. U.S. Dept. Agr. Misc. Pub. 303, 362 pp., illus.

272. Van Vechten, George Wendell.
1960. The ecology of the timberline and alpine vegetation of the Three Sisters, Oreg. Unpublished Ph.D. thesis on file Oregon State University, 111 pp., illus.

This study of the vegetation above 6,500-foot elevation in the Three Sisters area includes numerous observations on the occurrence and ecology of mountain hemlock. Mountain hemlock occurs in two of the physiographic zones delimited--"Ridge and outwash zone" and "Woods and meadows zone." In the former it predominates on the lower parts of the ridges (6,500- to 7,000-foot elevation) and occasionally on the outwash. In the latter, the forest is composed predominantly of dense stands of mountain hemlock; trees tend to grow on slight ridges and rises in this zone with small open areas between.

The dense hemlock forest of the "Woods and meadows zone" Van Vechten considers to be a stable community undergoing little change, with reproduction composed of essentially the same species. The most noticeable example of succession is where mountain hemlock is invading open areas because of a reduction in snowdrift size over the last 50 years. The meadows in the "Woods and meadows zone" are maintained primarily by late-persisting snowbanks which reduce the growing season and result in damage from snow fungi (Herpotrichia sp.) and snow creep. These snowbanks also result in water-logged soils during 9 months of the year and prevent germination of tree seed on the forest floor.

273. Warren, H. V., and Delavault, R. E.
1948. Biogeochemical investigations in British Columbia. Geophysics 13: 609-624.

274. _____, Delavault, R. E., and Fortescue, J. A. C.
1955. Sampling in biogeochemistry. Geol. Soc. Amer. Bul. 66: 229-238, illus.

Includes determinations of nickel content of mountain hemlock twigs and needles near mineralized areas.

275. _____, Delavault, R. E., and Irish, R. I.
1949. Biogeochemical research on copper in British Columbia. Roy. Soc. Canada Trans. 43: 119-147.

276. Warren, H. V., Delavault, R. E., and Irish, Ruth I.
1952. Biogeochemical investigations in the Pacific Northwest. Geol. Soc. Amer. Bul. 63: 435-484, illus.

277. _____ and Howatson, C. H.
1947. Biogeochemical prospecting for copper and zinc. Geol. Soc. Amer. Bul. 58: 803-820, illus.

Cones and needles of mountain hemlock offer possibilities for detecting unusual concentrations of copper.

278. Weaver, John E., and Clements, F. E.
1938. Plant ecology. Ed. 2, 601 pp., illus. New York: McGraw-Hill Co., Inc.

279. Weir, James R.
1915. Razoumofskya tsugensis in Alaska. Phytopath. 5: 229.

Weir concludes that this mistletoe extends throughout the range of its two hosts--western and mountain hemlocks.

280. _____
1916. Mistletoe injury to conifers in the Northwest. U.S. Dept. Agr. Bul. 360, 39 pp., illus.

Mountain hemlock frequently shows dead (spike) tops and brooming when heavily infected with dwarfmistletoe.

281. West, W. I.
1949. A collection of Oregon woods. Oreg. State Col. School Forestry Cir. 1, 31 pp., illus.

282. Whitford, Harry N., and Craig, Roland D.
1918. Forests of British Columbia. 409 pp., illus. Ottawa: Comn. Conserv. Canada.

283. Whittaker, R. H.
1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecol. Monog. 30: 279-338, illus.

Mountain hemlock and noble fir dominate forests growing on soils of quartz diorite origin above 5,800-foot elevation in the central Siskiyou Mountains of Oregon. Proportions of the two are not strongly correlated with elevation or site, suggesting that stand composition was to some extent determined by chance. There was some tendency, however, for mountain hemlock to dominate on the more mesic sites and at higher elevations. Similar forests also occupy the more mesic sites on soils

derived from periodotite and serpentine above 5,800-foot elevation. Floral descriptions of the noble fir–mountain hemlock communities are included.

284. Wilse, E.
1957. Veivesenets og Norges Statsbaners plantninger av snøskjermer (lebelter) pä høyfjellsovergangene. (Planting of snowbreaks (shelterbelts) by the Norwegian State Railways and the Road Board on mountain passes.) Norsk Skogbruk. 3: 99-100.

285. Winkenwerder, Hugo, and Wangaard, Frederick F.
1939. Short keys to the native trees of Oregon and Washington. 19 pp. Seattle: Imperial Publishing Co.

286. Wood, R. F.
1955. Studies of north-west American forests in relation to silviculture in Great Britain. Gt. Brit. Forestry Comn. Bul. 25, 42 pp., illus.

Mountain hemlock is a species worthy of trial at higher elevations and on poor peats in Great Britain. It was suggested that if seed lots are collected for test trials, a contrast be obtained between sources from low-level northern muskeg sites and high-level sites in Washington.

287. Wyman, Donald.
1943. Simple foliage key to the hemlocks and spruces. Arnoldia 3: 57-64, illus.

288. Wynd, F. Lyle.
1941. Life zones of Crater Lake. Amer. Midland Nat. 25: 324-342, illus.

Dense mountain hemlock forest occupies almost the entire Hudsonian zone at Crater Lake. Wynd felt this forest was so extensive and typical of the zone that it could be considered indicative of the Hudsonian zone throughout the Northwest. Noble fir is the common tree associate at lower elevations and whitebark pine at higher elevations. There is little or no understory vegetation in these forests. A list of typical associated plants is included.

289. Zach, Lawrence W.
1950. A northern climax, forest or muskeg? Ecol. 31: 304-306, illus.

Suggests that muskeg represents a physiographic climax over much of southeastern Alaska and cites several facts which support this conclusion. Mountain hemlock and lodgepole pine characteristically border muskeg or make up extensive stands on poorly drained sites.

290. Ziller, W. G.
1959. Studies of western tree rusts. V. The rusts of hemlock and fir caused by Melampsora epitea. Canad. Jour. Bot. 37: 109-119, illus.

SUBJECT INDEX

Anatomy (See also Wood technology, structure and properties) . . . . . 142, 152, 185, 194, 206, 243, 244, 245.

Autecologic factors (See also Damage and protection; Synecology) . . . . . 24, 53, 60, 87, 156, 157, 158, 224, 226, 227, 228, 238, 239, 250, 251, 254, 267, 272.

- atmospheric 206, 249
- biotic (See also Damage and protection; Synecology; Insects) 260
- fire 165, 166, 167, 197, 199
- light 13, 264
- soil . . . . . 34, 35, 43, 58, 59, 208, 209, 210, 211, 212, 234, 273, 274, 275, 276, 277, 283.
- temperature (See also Paleoecology) 115, 136, 187
- water (including snow; see also Paleoecology) 115, 136, 167, 179, 187, 215, 241, 283

Climatic factors (See Damage and protection; Autecologic factors)

Cover type (See also Distribution; Synecology) . . 10, 26, 30, 42, 47, 62, 68, 70, 94, 121, 125, 138, 165, 166, 214, 232, 242.

Cutting methods (See Autecologic factors; Regeneration, natural)

Damage and protection (See also Autecologic factors) 60, 243, 250, 251, 267, 272

- climatic 206
- disease and defect . . . . . 20, 21, 22, 48, 92, 96, 98, 122, 123, 124, 153, 159, 160, 165, 166, 207, 235, 244, 245, 258, 266, 279, 280, 290.
- fire 165, 166, 167, 197, 199
- insects (See Insects)

Dendrological references . . . . . 1, 5, 12, 16, 17, 19, 25, 27, 28, 29, 30, 32, 40, 45, 46, 61, 66, 67, 73, 76, 77, 78, 79, 82, 86, 90, 91, 93, 95, 120, 128, 139, 143, 144, 145, 146, 154, 168, 169, 170, 174, 180, 181, 184, 186, 191, 192, 193, 194, 195, 196, 202, 203, 204, 205, 213, 219, 220, 221, 222, 223, 248, 250, 251 252, 253, 256, 259, 271, 285, 287.

Distribution (See also Dendrological references) . . . . . .4, 7, 11, 14, 33, 34, 35, 41, 42, 47, 50, 53, 62, 63, 64, 70, 84, 87, 93, 94, 115, 127, 131, 136, 140, 148, 149, 155, 162, 165, 166, 167, 172, 179, 182, 188, 189, 197, 198, 200, 208, 209, 210, 211, 212, 216, 217, 218, 222, 224, 225, 226, 227, 228, 232, 233, 236, 240, 241, 249, 250, 251, 254, 257, 261, 267, 272, 278, 282, 283, 288, 289.

Economics (See Resources)

Floral manual references (See Dendrological references)

Genetics and hybridization . . . . . 36, 37, 38, 61, 72, 74, 83, 102, 126. 147, 268, 269.

Growth and development (See also Dendrological references) . . . 69, 83, 88, 165, 166, 167, 179, 187, 190, 197, 222, 239, 249, 250, 251, 256.

Insects . . . . . 31, 71, 89, 150, 151, 173, 201, 247, 262, 265.

Introduction in foreign countries 18, 24, 61, 77, 85, 284, 286

Light relationships (See Autecologic factors)

Lumber (See Utilization)

Paleoecology . . . . . 55, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 129, 130, 132, 133, 134, 135, 136, 164.

Pathological factors (See Damage and protection; Insects)

Paper (See Utilization)

Phenology 72, 75, 131, 165, 227

Phylogeny 36, 37, 38, 74, 83, 86, 126, 142, 265, 266

Physiology (See also Autecologic factors; Seed). 215

Properties (See Wood technology)

Protection (See Damage and protection)

Regeneration, natural 49, 99, 165, 166, 167, 246, 249, 254, 272

Resources 6, 121, 125

Roots 185, 260

Seed 72, 250, 251, 264, 270
destruction (See also Damage and protection) 151
germination and viability 9
production 15, 80, 81, 100, 141, 165, 179, 230, 231, 249
storage 229

Silviculture (See Autecologic factors; Damage and protection; Regeneration, natural; Synecology)

Statistics (See Resources)

Synecology (See also Autecologic factors; Distribution) . . . . . 2, 3, 53, 54, 60, 62, 63, 64, 65, 68, 127, 134, 148, 149, 156, 157, 158, 166, 167, 179, 187, 212, 218, 232, 238, 241, 254, 267, 272, 278, 283.
community relations . . . 7, 42, 94, 137, 138, 155, 165, 183, 258, 288
successional relations. . . . . 23, 35, 50, 51, 52, 55, 56, 57, 58, 59, 87, 163, 171, 255, 289.

Type (See Cover type)

Taxonomy (See Dendrological references; Phylogeny)

Utilization (See also Wood technology) . . . . . 8, 39, 60, 97, 98, 121, 125, 178, 190, 237, 271.

Vegetative reproduction 49, 171

Watershed management 44, 121, 165

Wood technology 281
chemistry of wood and tree products 161, 237
deterioration of trees and products (See also Damage and protection) 22, 97, 98, 206, 243, 244, 245
structure and properties. . . . . 39, 142, 152, 175, 176, 177, 190, 194, 206.

COMMON AND SCIENTIFIC NAMES OF TREE SPECIES ASSOCIATED WITH MOUNTAIN HEMLOCK AND NAMED IN CITED LITERATURE

Abies amabilis (Dougl.) Forbes	Pacific silver fir
Abies grandis (Dougl.) Lindl.	grand fir
Abies lasiocarpa (Hook.) Nutt.	subalpine fir
Abies magnifica A. Murr.	California red fir
Abies magnifica var. shastensis Lemm.	Shasta red fir
Abies procera Rehd.	noble fir
Alnus sinuata (Reg.) Rydb.	Sitka alder
Betula spp.	birch
Picea engelmannii Parry	Engelmann spruce
Picea glauca (Moench) Voss	white spruce
Picea sitchensis (Bong.) Carr.	Sitka spruce
Pinus albicaulis Engelm.	whitebark pine
Pinus contorta Dougl.	lodgepole pine
Pinus jeffreyi Grev. & Balf.	Jeffrey pine
Pinus monticola Dougl.	western white pine
Populus trichocarpa Torr. & Gray	black cottonwood
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir
Tsuga heterophylla (Raf.) Sarg.	western hemlock
Tsuga mertensiana (Bong.) Carr.	mountain hemlock

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